Chapter-1

Motion

Level-I

(For CBSE & Olympiads)

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Medical|IIT-JEE|Foundations

CHAPTER 1

Motion

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Motion is a common phenomenon observed in our daily lives. A moving bus, a running dog etc., show motion while a rock lying on the road does not show motion and we say it is at rest. Change in weather, day and night, sunset and sunrise, all are the consequences of the motion of the earth. But without mentioning the observer there is no point in mentioning the terms motion or rest. This chapter gives an insight of these terms. Like, what is the distance an air diver, must travel down the run way before reaching take off? When you throw a ball straight up in the air, how high does it go? When a glass slips from your hand how much time do you have to catch it before it hits the floor? By the end of this chapter you will be able to understand what motion is and how the physical quantities like velocity and acceleration help to describe it.

A typical sprinter speeds up during the one-third of a race and slows gradually over the rest of the course. Is it accurate to say that a sprinter is accelerating as he slows during the final two-thirds of the race?

STATE OF A BODY

Reference Point

The location (or position) of an object is described by specifying a reference point. The point from which location is observed and measured is called the reference point. This reference point is called **origin.**

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For example - If we say that a school is situated 5 km east of a temple. We have specified the position of the school with respect to the temple. In this example the temple is the reference point.

A system of geometric axis in relation to which measurements of size, position or motion can be made is called frame of reference.

Rest

If an object does not change its position with respect to a fixed point taken as a reference point in its surrounding with the passage of time, it is said to be at rest.

For example - A book placed on a table remains on the table, if not disturbed by anybody. Therefore, its position is not changing with respect to the table with the passage of time and we can say that the book is at rest with respect to the table.

Motion

An object is said to be in motion, if it changes its position with respect to a reference point in its surroundings with the passage of time.

For example - A moving car changes its position with respect to its surroundings with the passage of time.

Rest and Motion are Inter-related

An object may appear to be moving for one person and stationary for another person. Rest and motion are not significant without viewer. Nothing is at absolute rest or in absolute motion.

For example - A robber enters into a moving bus, brings out his knife and says, “don’t move, stand still.” The passengers stand still. The passengers are at rest with respect to the robber but are moving with respect to the road.

Hence, we conclude that the state of motion and rest is a combined property of the object under consideration and the observer.

Types of Motion

There are various types of motion as an object may move in various ways. An object moving in a straight line is said to have rectilinear motion. A body moving along a curved path is said to have curvilinear motion. An object moving around a fixed point has rotatory motion. The pendulum of a clock moves to-and-fro about the mean position and is said to have oscillatory motion. The motion of a sitar string, when plucked exhibits vibratory motion. If an object possesses two or more types of motion at the same time, then such a motion is called multiple motion. For example, the tyres of a truck moving along a straight road exhibit two types of motion, *i.e.,* rotatory motion as well as rectilinear motion.

The branch of physics which deals with the study of the motion of objects and their response to force is called mechanics.

Extra Shots

Scalar Quantity : A scalar quantity is specified by a single value with an appropriate unit and has no direction.

Examples : Mass, distance

Vector Quantity : A vector quantity must have magnitude as well as direction and obeys the laws of vector addition.

Example : Displacement, velocity

MOTION ALONG A STRAIGHT LINE OR RECTILINEAR MOTION

The simplest type of motion is the motion along a straight line, also known as rectilinear motion.

For example - A car is moving along a straight line path as shown below

Fig. 1

Distance or Path Length

It is the total path length covered by an object during the entire journey without taking into consideration its direction. It is a scalar quantity and is always positive for an object in motion.

Displacement

When a body moves from one position to another, the shortest distance between the initial and final position is said to be the magnitude of displacement and it is directed from initial to final position.

It is a vector quantity. It may be positive, negative or zero.

- ❖ When a body travels along a straight line in the same direction, then the distance it travels is equal to its displacement.
- ❖ There are various situations when a body has travelled a certain distance yet it has zero displacement.

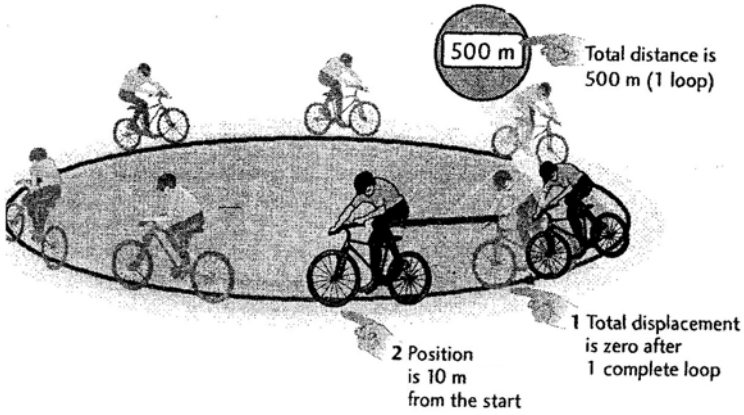
For example - If we take a round trip and come back to the starting point then, although we have travelled some distance, our net displacement will be zero because, the initial and final position are same.

Differences between distance and displacement

Distance	Displacement
1. It is the actual length of the path covered by a moving body irrespective of the direction in which it travels.	1. It is the shortest distance (straight distance) measured between the initial and the final position of a moving body in a particular direction.
2. It is a scalar quantity.	2. It is a vector quantity.
3. It is always positive or zero.	3. It may be positive, negative or zero.
4. It depends upon the path followed by the moving object.	4. It is independent of the path followed by the moving object.
5. It is always greater than or equal to the displacement.	5. Its magnitude is always less than or equal to the distance travelled.

Example 1 :

A cyclist travels around a 500 m circular track 10 times. What is the total distance and total displacement of the cyclist?



Solution :

The cyclist travels a distance of 500 m each time he completes one lap. Since he completes 10 laps, total distance travelled by him is 5000 m. To find his displacement, we draw a line segment from the starting point to the end point of his motion. Since he starts and ends at the same point, his displacement has a magnitude of zero.

Note : *In this example, we obtain different answers for distance and displacement. It is a good reminder of how important it is to clearly differentiate between the vector and the scalar quantities.*

Example 2 :

A person travels a distance of 4.0 m towards east, then turns left and travels 3.0 m towards north.

(i) What is the total distance travelled by the person?

(ii) What is the magnitude of his displacement?

Solution :

(i) Total distance

$= OA + AB$

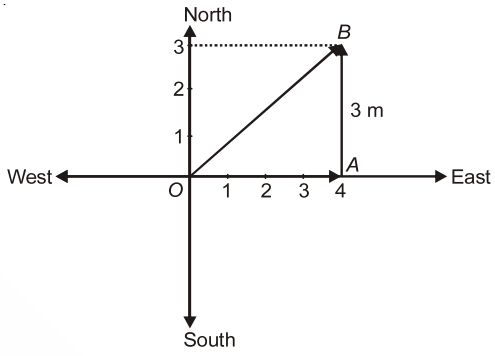
$= 4\text{ m} + 3\text{ m} = 7\text{ m}$

(ii) Total displacement $= OB = \sqrt{OA^2 + AB^2}$

$= \sqrt{(4)^2 + (3)^2}$

$= \sqrt{16+9}\text{ m} = \sqrt{25}\text{ m}$

$OB = 5\text{ m}$



Example 3 :

A person travels on a semi-circular track of radius 50 m during a morning walk. If he starts from one end of the track and reaches the other end. Calculate the distance travelled and the magnitude of displacement of the person.

Solution :

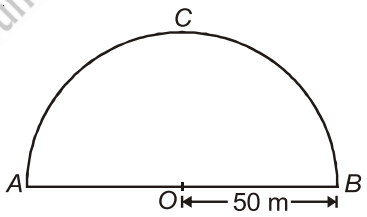
Let the person starts moving from A and reaches at B via C.
Then, the distance travelled by the person

= Length of the semi-circular track

$= \pi r = \frac{22}{7} \times 50\text{ m} = 157.14\text{ m}$

The displacement is equal to the diameter of the semi-circular track joining A to B via O.

$= 2r = 2 \times 50\text{ m} = 100\text{ m}$



Try Yourself

1. A body is moving along a circular path of radius r. What is the distance and displacement of the body, when it completes two and a half revolutions?
   (1) Distance is $5\pi r$ and displacement is $2\pi r$ (2) Distance is $2\pi r$ and displacement is $5\pi r$
   (3) Distance is $2r$ and displacement is also $2r$ (4) Distance is $5\pi r$ and displacement is $2r$
2. The numerical value of the ratio of displacement to distance is
   (1) Less than or equal to one (2) Always greater than one
   (3) Always less than one (4) Greater than or equal to one
3. Distance travelled by a body in a given time
   (1) Is always Positive (2) Can be zero or positive
   (3) Is always Negative (4) Either (1) or (3)

4. A person completes a round of circular track of radius R in 40 s. At the end of 2 minutes, displacement will be

   (1) $2\pi R$ (2) $3\pi R$

   (3) Zero (4) $7\pi R$

5. Which of the following is correct?

   (1) Magnitude of displacement may be greater than distance

   (2) Distance is always greater than or equal to the magnitude of displacement

   (3) Distance is always greater than the magnitude of displacement

   (4) Both are scalar quantities

[**Ans.** 1(4), 2(1), 3(2), 4(3), 5(2)]

SPEED AND VELOCITY

Speed

The speed of a body is defined as the distance travelled by it per unit time.

i.e., $\text{Speed} = \dfrac{\text{Distance travelled}}{\text{Time taken}}$

If a body travels a distance s in time t, then its speed v is given by

$$\boxed{v = \frac{s}{t}}$$

It is a scalar quantity. The SI unit of distance is metre (m) and that of time is second (s). Therefore, SI unit of speed is metre per second written as m/s or m s^{-1}. The other units of speed include centimetre per second (cm s^{-1}) and kilometre per hour (km h^{-1}).

Note : *While comparing the speeds of different bodies, we must convert all the speeds into same units.*

Average speed

It is defined as the total distance travelled by a body divided by the total time taken to cover this distance. It is a scalar quantity.

i.e., $\text{Average speed} = \dfrac{\text{Total distance travelled by the body}}{\text{Total time taken}}$

If a body travels a distance s in time t, then its average speed is $\bar{v}$.

$$\boxed{\bar{v} = \frac{s}{t}}$$

The SI unit of average speed is m/s. It can also be expressed in km/h or cm/s

Uniform Speed (or constant speed)

If an object covers equal distances in equal intervals of time, no matter how small these time intervals may be, then its speed is said to be uniform.

For example - A car running at a constant speed of 20 m/min, will cover equal distances of 20 m in every minute.

Non-Uniform Speed

If an object covers unequal distances in equal intervals of time, no matter how small these time intervals may be, then its speed is said to be non-uniform speed.

For example - (i) The motion of a car on a crowded road.

(ii) The motion of a freely falling body.

Velocity

Velocity of a body is the distance travelled by it per unit time in a particular direction. In other words, velocity is the speed of the body in a definite direction.

$$\text{Velocity} = \frac{\text{Distance travelled in a given direction}}{\text{Time taken}}$$

$\because$ Distance travelled in a given direction is the displacement of the object.

$$\therefore \quad \text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

Velocity has magnitude as well as direction. It is a vector quantity. Its unit is same as the unit of speed. Velocity of a body can be changed by changing its speed, direction of motion or both.

Average velocity

It is defined as the total displacement of a body divided by the total time taken to cover that displacement.

$$i.e., \text{ Average velocity} = \frac{\text{Total displacement of the body}}{\text{Total time taken}}$$

$$\boxed{v = \frac{x}{t}}$$

where, v = Average velocity

x = Total displacement of the body

t = Total time taken

If x_1 and x_2 are the positions of an object at times t_1 and t_2, then the average velocity from t_1 to t_2 is given by,

$$\text{Average velocity} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

When the velocity of a body moving in a straight line is changing continuously at a uniform rate, then the average velocity is given by the arithmetic mean of initial and final velocities for a given period of time.

$$i.e., \text{ Average velocity} = \frac{\text{Initial velocity + Final velocity}}{2}$$

Mathematically, $\boxed{v_{av} = \frac{u + v}{2}}$

where, v_{av} = Average velocity of the body

u = Initial velocity of the moving body

v = Final velocity of the moving body

Uniform velocity (Uniform motion)

A body is said to have uniform velocity, if it covers equal distances in equal intervals of time in a particular direction, no matter how small these time intervals may be. An object travelling with uniform velocity is said to have uniform motion along a straight line.

Example - A car moving along a straight line with a constant speed is said to have uniform velocity.

Variable velocity (Non-uniform motion)

A body is said to have variable velocity if

- ❖ It has non-uniform speed or
- ❖ Its direction of motion keeps on changing or
- ❖ Both its speed and direction changes with time.

An object travelling with non-uniform velocity is said to have non-uniform motion.

Example :

(i) A person running on a circular track.

(ii) A car moving on a crowded road.

Instantaneous Velocity and Speed

The average velocity and the average speed of an object tell us, how fast the object is moving in a given time interval, but it does not give information that how fast the object is moving at different instants. For example, a man drives from his home to office. His average speed can be found out by dividing the total distance travelled by him by the total time taken. But during his journey he increases or decreases the speed of the car *i.e.*, speed of the car is not same at different instants.

Instantaneous Velocity

The velocity of an object at a particular instant or at a particular point of its path is called instantaneous velocity *i.e.*, the instantaneous velocity of the object can be defined as the average velocity over an infinitesimally small time interval.

Instantaneous Speed

The speed at any instant of time is called the instantaneous speed. Generally, instantaneous speed is simply called speed.

Some Important Points :

- If an object moves along a straight line without changing its direction, then the magnitude of the average velocity is equal to the average speed.
- If a body is moving with a constant velocity, then the average velocity and instantaneous velocity are equal.
- When a body moves with velocities v_1 and v_2 for an equal interval of time t, then its average velocity is given by

$$v_{av} = \frac{v_1 + v_2}{2}$$

- When a body moves an equal distance s with velocities v_1 and v_2, its average velocity is given by

$$v_{av} = \frac{2v_1v_2}{v_1 + v_2}$$

- The odometer fitted in automobiles measures the distance travelled by it in kilometres, whereas the speedometer shows the instantaneous speed of the automobile.

Example 4 :

If an object is moving with velocity 54 km/h. What will be its velocity in

(i) m/s? (ii) km/min?

Solution :

We have,

velocity = 54 km/h

(i) In m/s,

$$v = 54 \times \frac{1000}{3600} = 15 \text{ m/s}$$

(ii) In km/min,

$$v = \frac{54 \text{ km}}{60 \text{ min}} = 0.9 \text{ km/min}$$

Example 5 :

The average velocity of Ram over a given time duration is 12 m/s. If he travels the first half of the total time with velocity x m/s and the second half of the total time with velocity 2x m/s. Calculate the value of x.

Solution :

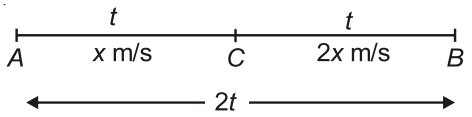
Let the total time be $2t$

Distance travelled by Ram in going from A to C

$$d_1 = x \times t = xt$$

Distance travelled by Ram in going from C to B

$$d_2 = 2x \times t = 2xt$$



Total distance = $d_1 + d_2 = (x + 2x)t = 3xt$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

$$12 = \frac{3xt}{2t}$$

$$3x = 24$$

$$\boxed{x = 8 \text{ m/s}}$$

Alternative method :

As, the velocity of Ram is changing at uniform rate

$$v_{av} = \frac{v+u}{2} = \frac{x+2x}{2} = \frac{3x}{2}$$

$$12 = \frac{3x}{2}$$

$$\boxed{x = 8 \text{ m/s}}$$

Example 6 :

The position of an object moving along x-axis is given by $x = a + bt^2$, where $a = 8.5$ m and $b = 2.5$ ms^{-2} and t is measured in seconds. What is average velocity between $t = 2$ s and $t = 4$ s?

Solution :

$$\text{Average velocity} = \frac{x_2 - x_1}{t_2 - t_1}$$

At $t = 2$ s, $x_1 = a + 4b$

At $t = 4$ s, $x_2 = a + 16b$

$$\text{Average velocity} = \frac{x_2 - x_1}{t_2 - t_1}$$

$$= \frac{(a+16b) - (a+4b)}{(4-2)}$$

$$= 6b$$

$$= 6(2.5) = 15.0 \text{ ms}^{-1}$$

Example 7 :

A motorist is moving with a constant speed of 45 km/h. How much distance will be covered by him in

(i) 1 min? *(ii) 1 h?* *(iii) 1 s?*

Solution :

We have been given,

Speed v = 45 km/h

(i) Distance travelled by him in one minute = speed (km/h) × time taken (h)

Time taken = 1 min = $\frac{1}{60}$ hour

$\therefore \quad x_1 = 45 \times \frac{1}{60} = 0.75$ km

$x_1 = 750$ m

(ii) Distance travelled by him in 1 hour is

x_2 = speed (km/h) × time (h) = 45 km

$x_2 = 45$ km

(iii) Distance travelled by him in 1 s

$$x_3 = v\,(\text{m/s}) \times \text{time taken (second)} = \frac{45000\ \text{m}}{3600\ \text{s}} \times 1\,\text{s}$$

$x_3 = 12.5$ m

Example 8 :

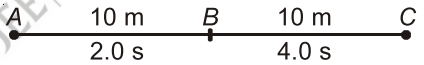
An object travels 10 m in 2 s and next 10 m in 4 s. What is the average speed of the object?

Solution :

Given

Total distance travelled = $AB + BC$ = 10 m + 10 m = 20 m

Total time taken = 6 s



$$\therefore \quad \text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

$$= \frac{20}{6} = 3.33\ \text{m/s}$$

The average speed of the object is 3.33 m/s.

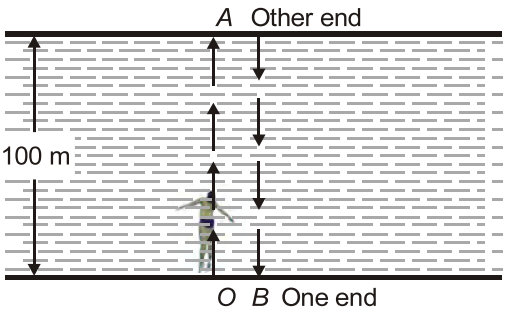
Example 9 :

A man swims in a pool of width 100 m. He covers 200 m in 10 minute by swimming from one end to the other, and back along the same path. Find the average speed and average velocity of man during the journey.

Solution :

Total distance covered by the man in 10 min = $OA + AB$

= 200 m



Displacement of the man in 10 min = 0

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}}$$

$$v_{av} = \frac{200\ \text{m}}{10 \times 60\ \text{s}} = \frac{1\,\text{m}}{3\,\text{s}} = 0.33\ \text{m/s}$$

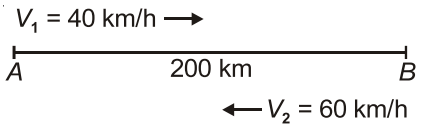
$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Total time taken}} = \frac{0\ \text{m}}{600\ \text{s}} = 0\ \text{m/s}$$

Therefore, the average speed of the man is 0.33 m/s and the average velocity is 0 m/s.

Example 10 :

A car travels a distance of 200 km along a straight road at a speed of 40 km/h. The car returns back to same location with a speed of 60 km/h. Find the average speed and the average velocity of the car for the entire journey.

Solution :



$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time}}$$

$$= \frac{400\text{ km}}{\frac{200\text{ km}}{40\text{ km/h}} + \frac{200\text{ km}}{60\text{ km/h}}} = \frac{400}{\frac{200}{10}\left(\frac{1}{4}+\frac{1}{6}\right)}\text{ km/h}$$

$$= \frac{20\times 24\text{ km}}{(6+4)\text{ h}} = 48\text{ km/h}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Time taken}} = 0$$

Because displacement is zero.

Alternative method :

$$V_{av} = \frac{2V_1V_2}{V_1+V_2} = \frac{2\times 40\times 60}{100} = 48\text{ km/h}$$

Example 11 :

Sachin jogs from one end A to the other end B of a straight road of length 300 m in 2 min 30 s. He then turns back and jogs 100 m to point C in 1 min. What are Sachin's average speed and average velocity in jogging.

(i) From A to B

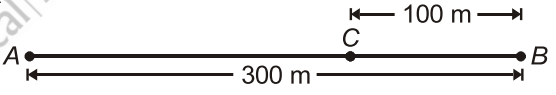
(ii) From A to C

Solution :

We have,

(i) Total distance d = 300 m

Total time taken t = 2 min 30 s = 150 s



$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

$$= \frac{300\text{ m}}{150\text{ s}} = 2\text{ m/s}$$

Thus, average speed from *A* to *B* is 2 m/s

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}}$$

$$= \frac{300\text{ m}}{150\text{ s}} = 2\text{ m/s}$$

It concludes that, if the magnitude of displacement is equal to the distance travelled, then average speed and the magnitude of average velocity are the same.

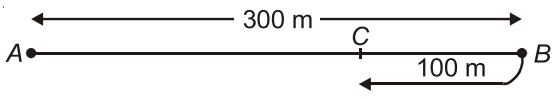
(ii) For *A* to *C*

Distance travelled = 400 m

Total displacement = 200 m

Total time taken = (2 min 30 s) + (1 min)

= 3 min 30 s = 210 s



$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

$$= \frac{400\text{ m}}{210\text{ s}} = 1.9\text{ m/s}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Total time taken}}$$

$$= \frac{200\text{ m}}{210\text{ s}} = 0.95\text{ m/s}$$

Thus, the average velocity from *A* to *C* is 0.95 m/s. It concludes that when the distance travelled and magnitude of displacement are unequal, the average speed and the magnitude of average velocity are different.

Example 12 :

A car moves at a speed of 2.24 km/h in the first minute, at a speed of 3.60 km/h in the second minute and at a speed of 5.18 km/h in the third minute. Calculate the average speed of the car in these three minutes.

Solution :

Distance travelled in the first minute

$$s_1 = v_1 \times t_1 = 2.24 \times \frac{1}{60}\text{ km}$$

Distance travelled in the second minute

$$s_2 = v_2 \times t_2 = 3.60 \times \frac{1}{60}\text{ km}$$

Distance travelled in the third minute

$$s_3 = v_3 \times t_3 = 5.18 \times \frac{1}{60}\text{ km}$$

Total distance travelled, $s = s_1 + s_2 + s_3$

$$s = \left(\frac{2.24}{60} + \frac{3.60}{60} + \frac{5.18}{60}\right)\text{ km} = \frac{11.02}{60}\text{ km}$$

Total time taken, $t = (1 + 1 + 1)\text{ min} = 3\text{ min} = \frac{1}{20}\text{ h}$

$$\therefore \quad \text{Average speed} = \frac{s}{t}$$

$$= \frac{11.02}{60} \times \frac{20\text{ km}}{1\text{ h}} = 3.67\text{ km/h}$$

Try Yourself

6. An artificial satellite is moving uniformly in a circular orbit of radius 42250 km. Find its speed if it takes 24 hour to revolve around the earth.
   (1) 1760.4 km/h (2) 3.07 km/h
   (3) 3.07 km/s (4) 1760.4 km/s
7. A person travels along a straight road for first half length with a constant speed v_1 and the second half length with a constant speed v_2. The average speed of the person is
   (1) $\frac{v_1 + v_2}{2}$ (2) $\frac{2v_1v_2}{v_1 + v_2}$
   (3) $\sqrt{v_1v_2}$ (4) $\sqrt{\frac{v_2}{v_1}}$

8. Choose the correct statement.
   (1) The average speed is always equal to the average velocity
   (2) The magnitude of average velocity is always less than or equal to the average speed
   (3) The magnitude of average velocity is always greater than or equal to the average speed
   (4) There is no difference between the average speed and the average velocity

9. A train 50 m long passes over a bridge at a speed of 30 km/h. If it takes 36 s to cross the bridge, the length of the bridge will be
   (1) 100 m (2) 200 m
   (3) 250 m (4) 300 m

10. A drunkard is walking along a straight road. He takes 5 steps forward and 3 steps backward, followed by 5 steps forward and 3 steps backward and so on. Each step is 1 m long and takes 1 second. There is a pit on the road 11 m away from the starting point. The drunkard will fall into the pit after
    (1) 21 s (2) 29 s
    (3) 31 s (4) 44 s

11. The average speed of an object over a given time duration is 6 m/s. If it travels first half of the duration with a constant speed 4 m/s, its speed during the next half duration is
    (1) 5 m/s (2) 4 m/s
    (3) 6 m/s (4) 8 m/s

12. An object is moving along the circumference of a circular track of radius R. What is the displacement of the object when it covers $\frac{3}{4}$th of its circumference?
    (1) $3R$ (2) $\frac{3}{2}\pi R$
    (3) $\frac{3}{4}\pi R$ (4) $\sqrt{2}R$

13. A man walks 5 m towards east and turns right and moves 12 m. The magnitude of his displacement is
    (1) 10 m (2) 20 m
    (3) 15 m (4) 13 m

14. A particle moving in a straight line covers half of the total distance with a speed of 3 m/s. The other half of the distance is covered in two equal time intervals with speeds of 4.5 m/s and 7.5 m/s. The average speed of the particle during this motion is
    (1) 4.0 m/s (2) 5.0 m/s
    (3) 5.5 m/s (4) 4.8 m/s

15. Average speed of a moving object is equal to the magnitude of its average velocity when it travels
    (1) In a straight line without turning back (2) In a circle
    (3) Back and forth (4) In a zig-zag path

[**Ans.** 6(3), 7(2), 8(2), 9(3), 10(2), 11(4), 12(4), 13(4), 14(1), 15(1)]

ACCELERATION AND RETARDATION

Acceleration

It is defined as the change in the velocity of an object per unit time.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

If the velocity of an object changes from an initial value u to final value v in time t, then acceleration a is given by

$$a = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time taken}}$$

$$\boxed{a = \frac{v-u}{t}}$$

This kind of motion is known as accelerated motion.

SI unit of acceleration is m/s^2

- ❖ It is a vector quantity, its direction is in the direction of change in velocity.
- ❖ It may be positive, negative or zero.
- ❖ If an object is moving with constant or uniform velocity, then its acceleration is zero.

Uniform Acceleration

A body is said to have uniform acceleration, if it travels in a straight line and its velocity increases or decreases by equal magnitude in equal intervals of time.

For example :

(i) The motion of a freely falling body.

(ii) The motion of a bicycle going down the slope of a road (when the rider is not pedaling and air resistance is negligible).

Non-uniform Acceleration

A body is said to have non-uniform acceleration, if its velocity changes by unequal magnitude in equal intervals of time.

For example - The motion of a car on a crowded road.

Retardation or Deceleration

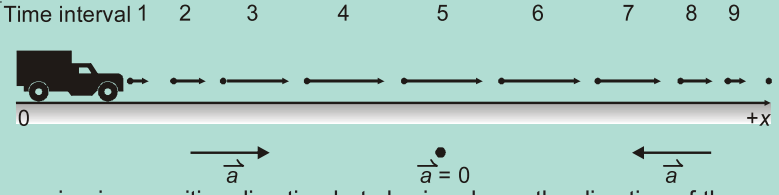
A body is said to be retarded if the magnitude of its velocity decreases with time. In this case, the final velocity of the moving body is less than the initial velocity *i.e.*, $v < u$.

For example - When a person applies brake on a moving car, its velocity decreases with time.

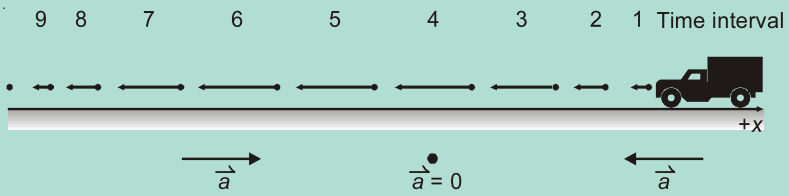
For example, if acceleration is $a = -5\ m/s^2$, we can write this as the deceleration or retardation is taking place at 5 m/s^2 or you can also put it as acceleration in the opposite direction at the rate of 5 m/s^2.

Knowledge Cloud

Figure shows the motion of a van that starts from rest, speeds up, travels at a constant velocity, slows down, and then stops. The given figure shows the origin at the left, with the x-axis pointing in a positive direction to the right. When the van is speeding up, the average velocity and the average acceleration point in the same direction (+). When the van is travelling at a constant speed, the average acceleration is zero. When the van is slowing down, the average velocity (+) and the average acceleration (–) are in opposite directions.



When the van is moving in a positive direction but slowing down, the direction of the acceleration is negative. Consider the directions that the average velocity and average acceleration point if the van turns around and travels back to its starting point. As shown in figure below, when the van is speeding up in a negative direction, both the average velocity and the acceleration point in the negative direction. When the van travels at constant velocity, the average velocity is negative and the acceleration is zero. As the van slows down to stop, the average velocity is pointing in the negative direction and the average acceleration is pointing in the positive direction.



When the van is moving in a negative direction and slowing down, the direction of acceleration is positive.

GRAPHICAL REPRESENTATION OF MOTION

(Distance or Position) - Time Graph

The change in the position of a body with time can be represented on a distance-time graph. In this graph time is plotted on *x*-axis and distance is plotted on *y*-axis.

From the distance-time graph we can get the following information :

(i) We can describe the nature of motion of the body whether it is uniform, non-uniform or the body is at rest.

(ii) We can determine the position of the body at any intermediate time (or any particular point of time).

(iii) We can calculate the speed of the moving body from the graph.

(1) Distance-time graph of a body moving with uniform speed

The distance-time graph for a body moving with uniform speed is a straight line as shown below. In other words we can say that if the distance-time graph is a straight line, the body is moving with uniform speed.

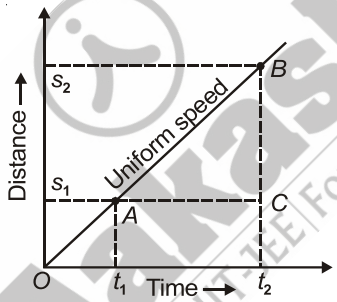


Fig. 2

Calculation of Speed from Distance-Time Graph

We consider two points *A* and *B*, on the distance-time graph as shown in Fig. 2. Draw a line parallel to *x*-axis from *A* and another line parallel to *y*-axis from *B*. These lines intersect each other at *C* to form a ΔABC. On the graph,

$AC = (t_2 - t_1)$ = time interval, and

$BC = s_2 - s_1$ = Distance travelled

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}}$$

$$= \frac{s_2 - s_1}{t_2 - t_1} = \frac{BC}{AC}$$

But $\frac{BC}{AC}$ is known as the slope of the line *OAB*.

Therefore, in distance-time graph, the speed of the body is given by the slope of the graph.

(2) Distance-Time Graph for a Body Moving with Non-uniform Speed

The distance-time graph for a body moving with non uniform speed is not a straight line but a curve. Therefore, we can say that if the distance-time graph of a body is a curve, the body is moving with non-uniform speed.

(a) Increasing Speed

A typical graph for a body moving with variable speed is shown in figure 3. In the graph, the slope changes at every point. The slope increases, so the speed increases.

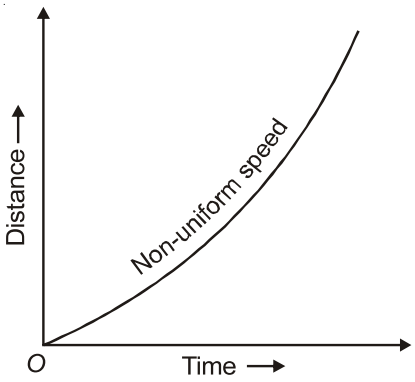


Fig. 3

(b) Decreasing Speed

The distance-time graph of an object, that is slowing down, is shown below.

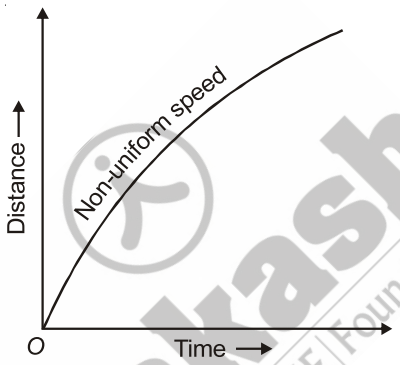


Fig. 4

This graph shows the speed of the object is decreasing with time. The slope decreases so the speed decreases.

(3) Position-Time Graph for a Body at Rest

The position-time graph for a body at rest is a straight line parallel to *x*-axis (time axis).

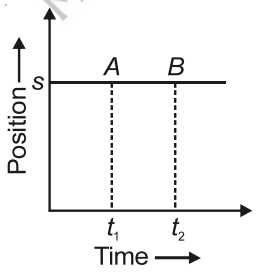


Fig. 5

Interpretation

At two points *A* and *B*, time has changed but the position of the body is same, so we can say that the body is at rest.

Determination of Speed

Consider the small portion *AB* of the position-time graph (figure 5.)

Position at time t_1 = s

Position at time t_2 = s

Distance covered by the body in time interval t_1 to t_2 = $s - s = 0$

Time taken = $t_2 - t_1$

$$\text{Speed} = \frac{\text{Distance travelled}}{\text{Time taken}} = \frac{s - s}{t_2 - t_1} = 0$$

Thus, the speed of the body at rest is zero

In all the above cases, if we consider the displacement on *y*-axis, then we will get displacement-time graph and we can determine the velocity of the body from that graph.

(I) Uniform velocity

The body having uniform velocity is said to have uniform motion. The graph for a uniform velocity is a straight line, as shown below.

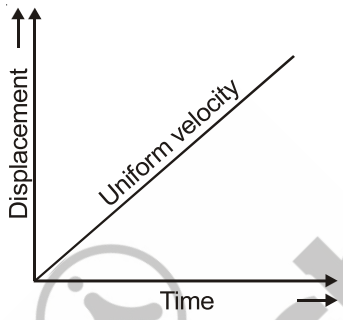


Fig. 6 : Graph showing uniform velocity

(II) Non-Uniform velocity

The graph for a non-uniform velocity is not a straight line, but a curve.

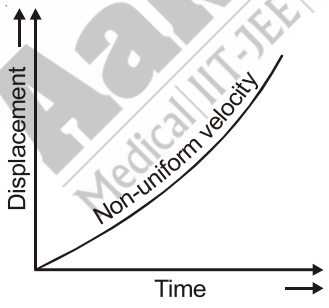


Fig. 7 : Graph showing variable (non-uniform) velocity

Velocity-Time Graph

The variation in velocity with time for a body moving in a straight line can be represented by a velocity-time graph. In this graph, time is plotted on *x*-axis and velocity is plotted on *y*-axis. From the velocity-time graph we can get the following information.

(i) We can determine the velocity of the moving body at any particular point of time and the nature of the motion.

(ii) We can determine the acceleration of the body. The slope of the velocity-time graph gives the magnitude of the acceleration of the body.

(iii) By calculating area under the graph, we can find the magnitude of displacement travelled by the body in a given time interval

(1) When the object is moving with constant velocity (Uniform Motion)

(i) The straight line parallel to time axis shows constant velocity.

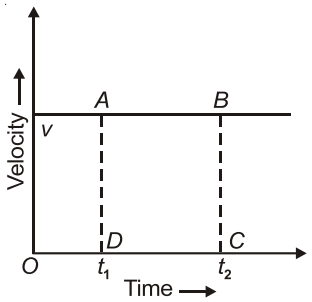


Fig. 8

(ii) **Calculation of the acceleration of the body from the velocity-time graph (Fig. 8).**

Velocity of the body at time t_1 = v m/s

Velocity of the body at time t_2 = v m/s

Change in velocity = $v - v = 0$

Time taken = $t_2 - t_1$

$$a = \frac{\text{Change in velocity}}{\text{Time taken}} = 0$$

$\therefore$ **The acceleration of a body moving with constant velocity is zero.**

(iii) **Calculation of displacement from the velocity-time graph (Fig. 8).**

To find the displacement travelled by the body (say a car) for a given time interval t_1 to t_2, draw perpendicular from t_1 and t_2 such that they intersect the straight line graph at A and B respectively. We will get a closed figure $ABCD$.

The displacement of the body = Velocity × time taken

= $v \times (t_2 - t_1)$ = $AD \times CD$ = Area of rectangle $ABCD$

Thus, **the area enclosed by the velocity-time curve and the time axis gives the displacement of the body in a given interval of time.**

(2) When a body is moving with uniform acceleration (Non-uniform Motion)

(i) When the body is initially at rest

(a) If the body initially at rest starts moving with uniform acceleration, then the velocity-time graph is a straight line starting from origin.

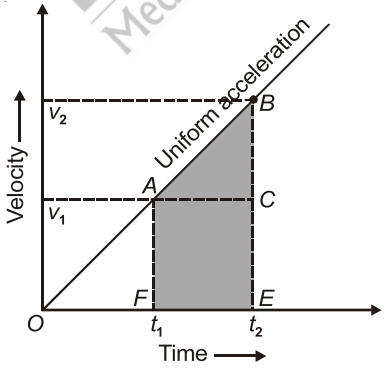


Fig. 9

(b) $$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{BC}{AC} = \text{Slope of line } OAB$$

$\therefore$ The slope of the line gives the acceleration of the body moving with uniform acceleration.

(c) Displacement of the body in the given time interval $(t_2 - t_1)$ can be calculated by the area of the shaded portion under the velocity-time curve.

Thus,

Displacement = Area of the shaded portion under the curve = Area of *ABCEF* = Area of a ΔABC + area of a rectangle *ACEF*

$$= \frac{1}{2} AC \times BC + AF \times FE$$

(ii) When the body is initially not at rest

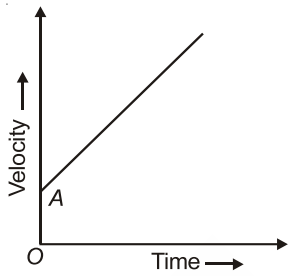


Fig. 10

Velocity-time graph of a body, initially not at rest and moving with uniform acceleration, is a straight line. But it does not originate from origin *O*. It will originate from some point *A* on velocity axis. It means at time $t = 0$, it has some non-zero velocity v (say).

(3) When a body is moving with uniform retardation (Non-uniform Motion)

The velocity-time graph of a body moving with uniform retardation is a straight line sloping downwards. The slope of such a straight line graph is said to be negative.

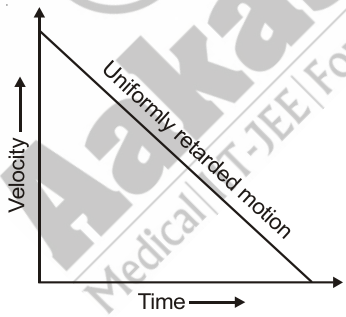


Fig. 11

(4) When a body is moving with non-uniform acceleration

In the case of non-uniformly accelerated motion, the velocity-time graph can have various shapes :

(i) When the velocity of a body increases non-uniformly

In this case, velocity-time graph is a curve moving upwards. Here, the slope of the curve is positive and increasing with time.

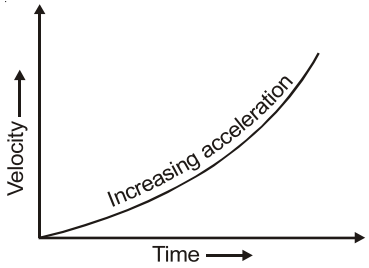


Fig. 12

(ii) When the velocity of a body decreases non-uniformly

In this case, the body is under non-uniform retardation. Therefore, the velocity decreases non-uniformly, the velocity-time graph is a curve moving downward. The slope of the curve is negative.

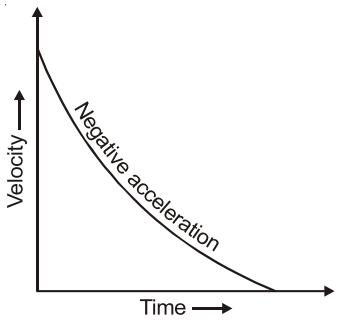


Fig. 13

(iii) When the velocity of the body increases and decreases non-uniformly

In the graph,

$OA \rightarrow$ Represents uniformly accelerated motion

$AB \rightarrow$ Represents uniformly decelerated motion

$BC \rightarrow$ Represents uniformly accelerated motion

$CD \rightarrow$ Represents uniformly decelerated motion

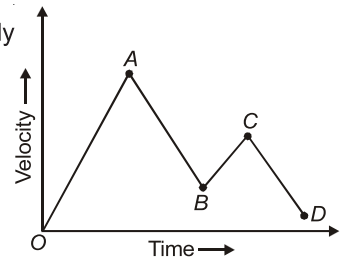


Fig. 14

DERIVATION OF EQUATIONS OF MOTION BY GRAPHICAL METHOD

If an object is moving along a straight line with uniform acceleration, then its displacement (s), time taken (t), initial velocity (u), final velocity (v) and acceleration (a) are related to one another by a set of equations known as equations of motion. These are

$$v = u + at \quad \ldots(i)$$

$$s = ut + \frac{1}{2}at^2 \quad \ldots(ii)$$

$$v^2 = u^2 + 2as \quad \ldots(iii)$$

Velocity-Time Relation

Let the object is moving with uniform acceleration and has some initial velocity u and its velocity increases to v in time t. We plot a graph between velocity and time for the motion (figure 15).

At $t = 0$, velocity $= u$

At $t = t$ second, the velocity becomes v

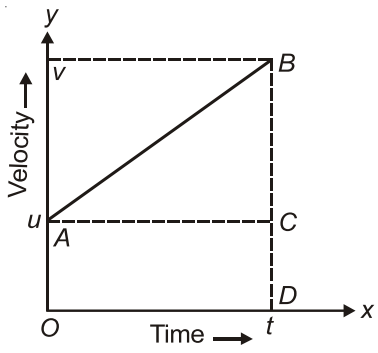


Fig. 15

We know that the acceleration of a body is equal to the slope of the velocity-time graph.

Thus,

$$a = \frac{BC}{AC} = \frac{v-u}{t-0}$$

$$v - u = at$$

$$\boxed{v = u + at}$$

This is the first equation of motion.

Position-Time Relation

Displacement of the body(s) = Area under the velocity-time curve

s = Area of ΔABC + Area of rectangle $OACD$

$$s = \frac{1}{2} \times AC \times BC + OA \times OD$$

$$s = \frac{1}{2}(t-0)(v-u) + u(t-0)$$

$$\therefore \quad \boxed{s = ut + \frac{1}{2}at^2} \qquad (\because \quad v - u = at)$$

This is the second equation of motion.

Position-Velocity Relation

The velocity-time graph, the displacement covered by the object in time t, moving with uniform acceleration a, is given by the area of trapezium $OABD$.

$$\therefore \quad s = \frac{(OA + BD)}{2} \times OD = \left(\frac{u+v}{2}\right).t$$

but $v = u + at \Rightarrow t = \dfrac{v-u}{a}$

$$\therefore \quad s = \left(\frac{u+v}{2}\right).\left(\frac{v-u}{a}\right)$$

$$\boxed{v^2 = u^2 + 2as}$$

This is the third equation of motion.

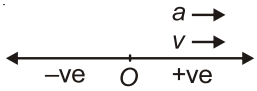
> ***Note :*** *These equations are applicable only when body moves with uniform acceleration.*

SIGN CONVENTION

Vector quantities have magnitude as well as direction, which cannot be ignored. So, while dealing with vector quantities we must pay attention towards their direction. As the equations of motion involve vector quantities such as velocity, acceleration and displacement, we must define some sign conventions for dealing with these quantities.

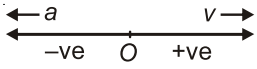
1. The point where the object is at $t = 0$, is taken as origin.
2. We are free to choose any direction as positive or negative.

(a) If we are taking right hand side as positive and left hand side as negative as shown below, and both v and a are along the positive direction, then the velocity of the object is increasing *i.e.*, it is accelerating.

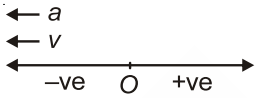


❖ Both acceleration and velocity are positive.

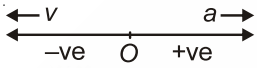
(b) If v and a are in opposite direction, velocity is decreasing with time *i.e.*, the object is retarding.



(c) If both v and a are along L.H.S. *i.e.,* along negative direction, object is accelerating, its velocity is increasing with time.

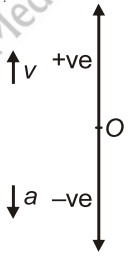


(d) If v is along the negative direction and a is along positive direction then, the object is retarding.

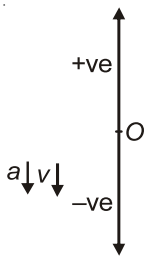


(e) Now, consider the vertical motion. If we take upward direction as positive, and downward direction as negative and both v and a are in the upward direction, then object is accelerating upwards.

(f) If a and v are in the opposite direction, then the object is retarding *i.e.,* its velocity is decreasing with time.



(g) If a and v are in the downward direction (–ve), then its velocity increases *i.e.,* the object accelerates downwards.



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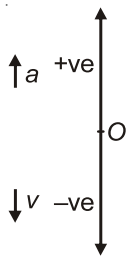
(h) If velocity is along the downward direction and acceleration is along the upward direction, the velocity of object decreases with time.



Some Important Points :

(i) If a body starts from rest, then $u = 0$.

(ii) If a body stops or comes to rest, then $v = 0$.

(iii) If a body moves with a constant velocity, then $a = 0$.

(iv) For converting speed from km/h to m/s multiply it by $\frac{5}{18}$.

(v) While calculating displacement from *v-t* graph give due regard to the positive and the negative signs. For calculating distance, only positive sign is to be used.

(vi) When an object's velocity and acceleration are in the same direction, the object is speeding up. On the other hand, when the object's velocity and acceleration are in opposite directions, the object is slowing down.

Example 13 :

A car starting from rest attains a velocity of 60 km/h in 10 minutes. Calculate the acceleration and distance travelled by the car, assuming that the acceleration is uniform.

Solution :

Given,

$u = 0$, $v = 60$ km/h $= 60 \times \frac{5}{18}$ m/s $= \frac{50}{3}$ m/s

$t = 10$ min. $= 10 \times 60$ s $= 600$ s

From the velocity-time relation,

$$v = u + at \Rightarrow a = \frac{v-u}{t} = \frac{\frac{50}{3} - 0}{600} = \frac{5}{180} \text{ m/s}^2$$

$$= 0.028 \text{ m/s}^2$$

We have,

$v^2 = u^2 + 2as$

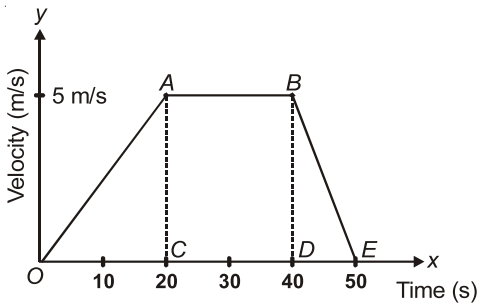
$$s = \frac{v^2 - u^2}{2a} = \frac{\left(\frac{50}{3}\right)^2 - 0^2}{2 \times \frac{5}{180}} = \frac{50 \times 50 \times 180}{2 \times 9 \times 5}$$

$$= 5000 \text{ m} = 5 \text{ km}$$

The acceleration of the car is 0.028 m/s^2 and the distance covered is 5 km.

Example 14 :

The motion of a car is described by the velocity-time graph as shown in the figure given below.



Find the distance travelled by the car between

(i) 0 to 20 s

(ii) 20 to 50 s

Solution :

We know that,

Distance travelled = Area under *v*-*t* graph

(i) For (0 to 20) s,

Distance = Area of ΔOAC

$$= \frac{1}{2} \times OC \times AC = \frac{1}{2} \times 20 \times 5 = 50 \text{ m}$$

(ii) For (20 to 50) s,

Distance = Area of rectangle *ABDC* + Area of ΔBED

$$\text{Distance} = AC \times CD + \frac{1}{2} DE \times DB$$

$$= 5 \times (40 - 20) + \frac{1}{2} \times 10 \times 5$$

$$= 100 + 25 = 125 \text{ m}$$

Thus, distance travelled by the car from 0 to 20 s is 50 m and from 20 s to 50 s is 125 m.

Example 15 :

A train starting from a railway station and moving with uniform acceleration attains a speed of 40 km/h in 10 minutes. Find its acceleration.

Solution :

We have,

Initial velocity u = 0 km/h

Final velocity v = 40 km/h

$$\text{Time } t = 10 \text{ min} = \frac{10}{60} \text{ h}$$

Using formula for acceleration,

$$\text{i.e. } a = \frac{v - u}{t}$$

$$= \frac{40 - 0}{\frac{10}{60}} = 240 \text{ km/h}^2$$

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Example 16 :

A car moving with a speed of 54 km/h is brought to rest in 10 seconds by applying brakes. Find the magnitude of average retardation due to brakes.

Solution :

Initial velocity (u) = 54 km/h

$$= 54 \times \frac{5}{18} = 15 \text{ m/s}$$

Final velocity (v) = 0 m/s

Time interval t = 10 s

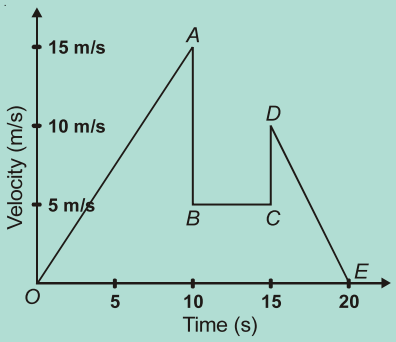
We have, $a = \frac{v-u}{t} = \frac{0-15}{10} = -1.5 \text{ m/s}^2$

Here, negative signs show retardation

$\therefore$ The magnitude of average retardation = 1.5 m/s^2

Try Yourself

The velocity-time graph for a particle is shown in the figure, then

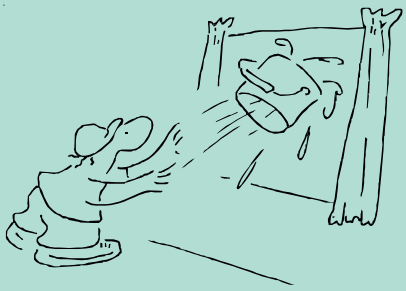


16. The distance and displacement of the particle from 0 to 15 seconds is
    (1) 100 m, 50 m (2) 100 m, 100 m
    (3) 100 m, 200 m (4) 100 m, 0
17. The distance and displacement of the particle between 10 s to 20 s is
    (1) 50 m, 100 m (2) 50 m, 0
    (3) 50 m, 50 m (4) 100 m, 50 m
18. In which time interval the particle is speeding up?
    (1) 0 to 10 s (2) 10 to 15 s
    (3) 15 to 20 s (4) 10 to 20 s
19. In which time interval the particle is moving with zero acceleration?
    (1) 0 to 5 s (2) 5 to 10 s
    (3) 10 to 15 s (4) 15 to 20 s
20. In which time interval the particle is moving with negative acceleration?
    (1) 5 to 10 s (2) 10 to 15 s
    (3) 15 to 20 s (4) 0 to 5 s

[Ans. 16(2), 17(3), 18(1), 19(3), 20(3)]

FUN ZONE

Why did the boy throw a bucket of water out of the window?



He wanted to see the Waterfall.

Waterfall is a compound word that refers to water falling straight down over rocks, usually from a high place. For example, Niagara Falls is a famous waterfall. The meaning of this compound word is easy to understand from the separate words that make it up : water and fall.

UNIFORM CIRCULAR MOTION

When an object moves in a circular path with uniform speed, its motion is said to be uniform circular motion.

Example - Motion of the tips of hands of a clock, a car moving on a circular track with constant speed.

The speed of an object moving along a circular track is given by

$$v = \frac{\text{Length of the circular path travelled by the object}}{\text{Time taken}}$$

$$\boxed{v = \frac{2\pi r}{t}}$$

$r \rightarrow$ Radius of circular track

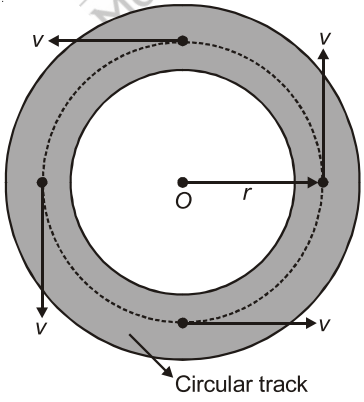


Fig. 16

- Velocity of the object at any point on circular path is along the tangent to the circle at that point.
- The motion in a circle with constant speed is an example of accelerated motion, because at every point the direction of motion changes, hence velocity changes.

QUICK RECAP

1. **State of rest :** A body is said to be at rest if it does not change its position with respect to a fixed point taken as a reference point in its surroundings with the passage of time.
2. **State of motion :** A body is said to be in motion if it changes its position with respect to a fixed point taken as a reference point in its surroundings with the passage of time.
3. **Types of motion :** The various types of motion are rectilinear motion, curvilinear motion, oscillatory motion, vibratory motion, multiple motion.
4. **Mechanics :** The branch of physics which deals with the study of motion of objects and their response to force is called mechanics.
5. **Distance travelled :** The actual length of the path travelled by a moving body in a given interval of time irrespective of the direction in which the body travels is called the distance travelled by that body.
6. **Displacement :** The shortest distance (straight distance) measured between the initial position and the final position of a moving body in a particular direction is called its displacement.
7. **Uniform motion :** A body moving in a straight line has a uniform motion if it travels equal distances in equal intervals of time, no matter how small these time-intervals may be.
8. **Non-uniform motion :** A body has a non-uniform motion if it travels unequal distances in equal intervals of time, no matter how small these time-intervals may be or its direction keep on changing.
9. **Average speed** $= \dfrac{\text{total distance travelled}}{\text{total time}}$.
10. **Instantaneous speed :** The speed at any instant of time is called the instantaneous speed. It is equal to the magnitude of instantaneous velocity.
11. **Uniform velocity :** A body is said to have uniform velocity if it covers equal displacement in equal intervals of time, no matter how small these time intervals may be.
12. **Variable velocity :** A body is said to have variable velocity if it covers unequal distances in equal intervals of time in a particular direction, no matter how small these time-intervals may be, or if it covers equal distances in equal interval of time but its direction keep on changing or if both its direction and speed changes with time.
13. **Acceleration :** The rate of change of the velocity of a body with respect to time is called its acceleration.
14. **Retardation :** When acceleration of body is opposite to its velocity, it is called retardation.
15. **Distance-time graph :** A graph showing the distance covered with time is called its distance-time graph.
    (i) For a body moving with uniform speed it is a straight line, inclined to the time-axis.
    (ii) For a body moving with non-uniform speed it is a curve.
    (iii) For a body at rest it is a straight line parallel to the time-axis.
16. **Velocity-time graph :** A graph showing the variation of velocity with time is called velocity-time graph.
    (i) The shape of the velocity-time graph depends upon the nature of motion of the body.
    (ii) The slope of the velocity-time graph gives the acceleration of the body.
    (iii) The area under the velocity-time graph gives the displacement the body in that interval of time.
17. **Uniform circular motion :** When an object is moving in a circular path with a constant speed, the motion of the object is said to be uniform circular motion. Uniform circular motion is an accelerated motion.

❑ ❑ ❑

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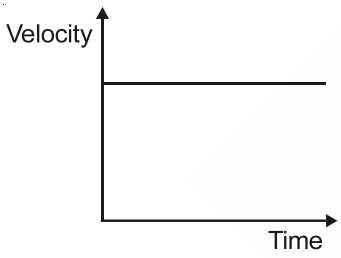
Assignment

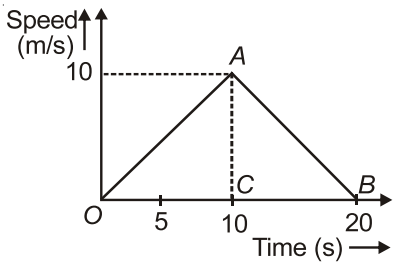
SECTION-A

Very Short Answer Type Questions :

1. Give one example where the displacement is zero but the distance travelled is not zero.
2. What is the nature of the motion of a body for which velocity-time graph is shown in figure?



3. When are the following true for the path length?
   (i) It is zero.
   (ii) It is greater than the magnitude of displacement of the object.
4. What does the odometer of an automobile measure?
5. What is the nature of the displacement versus time graph for non-uniform motion? Give an example.
6. Area under velocity-time curve represents which physical quantity?
7. What is the distance travelled by an object from t = 0 to t = 10 s in the following graph?



8. A person moves along the boundary of a square park of side 10 m in 40 s. What will be the magnitude of displacement of the person at the end of 3 minutes?
9. Fill in the blanks:
   (a) _____ of the velocity-time graph gives acceleration of an object.
   (b) Every motion is _____ to some reference.
   (c) For the displacement and distance travelled to be the same the _____ taken must be straight.
   (d) Speed is always _____.
   (e) On a position-time graph, the slope of the line tells you the _____ of the object.
   (f) For your total displacement to be zero you must end up back from where you _____.
   (g) Straight line parallel to time axis in a _____ time graph shows uniform motion of an object.
   (h) If a car accelerates, there is an _____ in its speed.
   (i) Acceleration of a falling object arises due to the force of _____.
   (j) Wet road conditions affect the _____ distance of a car.

Short Answer Type Questions :

1. A car travels first 10 km in 20 minutes and another 10 km in 30 minutes. What is the average speed of the car in m/s?
2. A student while going to school in a school bus, observes the average speed of the bus to be 20 km/h. On his return trip along the same way, the average speed is 30 km/h. What is the average speed of the bus in the entire journey?

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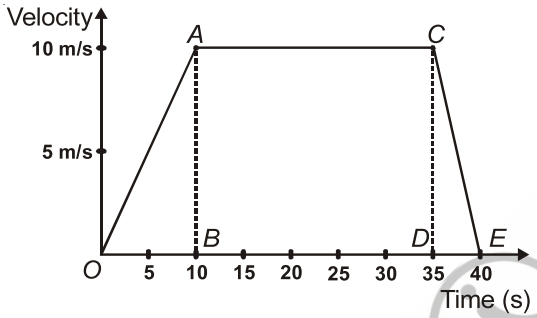
3. A car moving with a velocity 54 km/h on a straight road stops on applying brakes after covering a distance of 20 m. Compute the acceleration of the car.

4. A person on a morning walk completes one round around a circular park of diameter 500 m, in 1 minute. What will be the distance covered and the displacement at the end of 5 minutes 30 s?

5. A body is moving uniformly in a straight line with a velocity 10 m/s. What is the distance covered by it in 10 s? (calculate it with the help of velocity versus time graph)

6. The velocity-time graph of a ball is given below.



What is the acceleration of the ball

(i) During first 10 s?

(ii) Between 10 s and 35 s?

(iii) During 35 s to 40 s?

7. Derive position-time relation by graphical method.

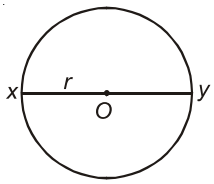
8. A car acquires a velocity of 40 km/h in 30 s just after the start. Calculate the acceleration of the car.

9. On a 200 km track, a train travels the first 50 km at a uniform speed of 40 km/h. How fast the train must travel the next 150 km so as to maintain the average speed of 60 km/h for the whole journey?

10. A man travels a distance 8 m towards north then turns left and moves towards west 6 m. What is the total distance and displacement from the starting point of his journey?

11. An object moving with initial velocity u along a straight line attains maximum velocity v after travelling distance s. Assume the acceleration is uniform. Derive the relationship between position and velocity of the object by graphical method.

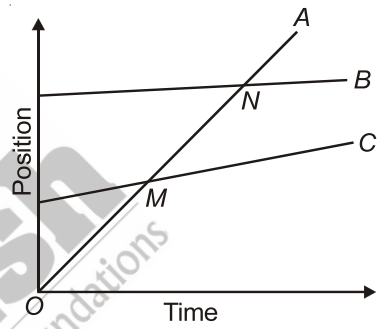
12. A cyclist moves from a certain point x and goes round a circle of radius r and reaches y exactly at the other side of the point x as shown in figure. What is the distance and displacement of the cyclist during the journey?



13. The brakes applied to a car produce an acceleration of 10 m/s^2 in the opposite direction to the motion. If it takes 5 s to stop after the application of brakes, then how much distance is covered by the car before coming to rest?

Long Answer Type Questions :

1. Derive an expression for velocity-time relation by graphical method. The position-time graph of three particles A, B and C are shown in the figure. Study the graphs and answer the following questions :



(i) Which of the particle is travelling fastest?

(ii) Will they ever meet each other?

(iii) Are they travelling uniformly?

2. A particle starts with an initial velocity 2.5 m/s along the positive x-direction and it accelerates uniformly at the rate 0.5 m/s^2.

(i) Find the distance travelled by it in the first two seconds.

(ii) How much time does it take to attain the velocity 7.5 m/s?

(iii) How much distance will it cover in attaining the velocity 7.5 m/s?

3. On a foggy day, two car drivers spot each other, when they are just 80 m apart. They are travelling at 72 km/h and 60 km/h respectively towards each other. Both of them simultaneously apply brakes, which retard both the cars at a rate of 5 m/s^2. Determine whether they avert the collision or not.

4. When the traffic light turns green, a car moves with a constant acceleration 2 m/s^2. At the same time a truck moving with a constant speed of 10 m/s, overtakes and passes the car.

(i) How far beyond the starting point will the car overtake the truck?

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(ii) How fast will the car be travelling at that instant?

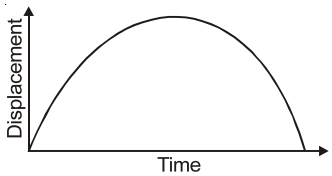
(iii) Draw position-time curve for each vehicle.

5. Define uniform velocity of an object moving along a straight line. What will be the shape of velocity-time and position-time graphs for such motion?
6. How will you differentiate between the distance covered by an object and its displacement? Write the important characteristics of distance travelled and displacement.
7. Show that area under the velocity-time curve of a body moving uniformly gives the displacement of the particle in a given time.
8. A metro train starts from rest and in five seconds achieves 108 km/h. After that it moves with constant velocity and comes to rest after travelling 45 m with uniform retardation. If total distance is 395 m, then find the total time of travelling of the metro.
9. Derive with help of graphs, the three equations of motion.

SECTION-B

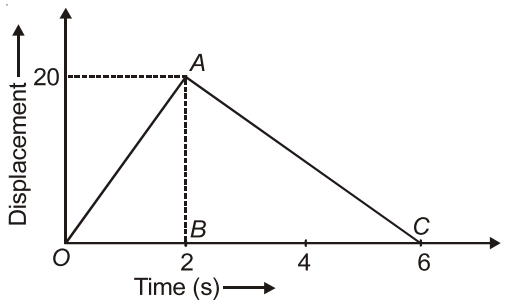
Objective Type Questions :

1. The ratio of speed to the magnitude of velocity when the body is moving in one direction is
   (1) Less than one
   (2) Greater than one
   (3) Equal to one
   (4) Greater than or equal to one
2. A ball strikes the floor vertically downward with a speed 5 m/s and rebounds with the same speed. The magnitude of its change in velocity will be
   (1) Zero (2) 5 m/s
   (3) 10 m/s (4) 40 m/s
3. If a body is travelling along a straight line without changing the direction of motion, then
   (1) Speed = |velocity|
   (2) Distance travelled = |displacement|
   (3) Average speed = |average velocity|
   (4) All of these
4. A car moving on a straight road covers the one third of the total distance with 20 km/h and the rest with 60 km/h. The average speed is
   (1) 40 km/h (2) 36 km/h
   (3) 26 km/h (4) 80 km/h
5. A boy goes from *A* to *B* with a velocity of 20 m/min and comes back from *B* to *A* with a velocity of 30 m/min. The average velocity of the boy during the whole journey is
   (1) 24 m/min (2) 25 m/s
   (3) Zero (4) 20 m/min
6. A train travels the first 15 km at a uniform speed of 30 km/h, next 10 km at a uniform speed of 20 km/h and final 75 km at a uniform speed of 50 km/h. The average speed for the entire journey of the train is
   (1) 40 km/h (2) 50 km/h
   (3) 40 m/s (4) 50 m/s
7. If the velocity of a body does not change, then its acceleration is
   (1) Zero
   (2) Unity
   (3) Infinity
   (4) Between zero and unity
8. A car increases its speed from 20 km/h to 50 km/h in 10 seconds. Its acceleration is
   (1) 0.30 m/s^2 (2) 0.18 m/s^2
   (3) 0.83 m/s^2 (4) 0.50 m/s^2
9. Which of the following situations is possible?
   (1) An object can have acceleration, but constant velocity
   (2) The velocity of an object may be zero but acceleration is not zero
   (3) Distance and the magnitude of displacement are equal in circular motion
   (4) Average speed and the magnitude of average velocity are always equal in circular motion
10. When a graph between two physical quantities is a straight line passing through the origin with positive slope, then the two quantities are
    (1) Constant
    (2) Independent of each other
    (3) Directly proportional to each other
    (4) Inversely proportional to each other
11. The graph predicts the condition of



    (1) Body is undergoing positive acceleration
    (2) Body is undergoing negative acceleration
    (3) Uniform velocity
    (4) Uniform speed

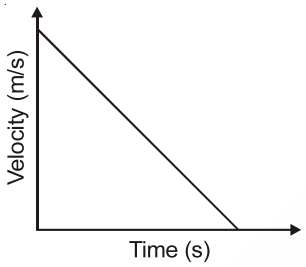
12. For the displacement-time graph of a car as shown in figure, the ratio of the magnitudes of the velocity during the first two seconds and the next four seconds is



(1) 1 : 1 (2) 2 : 1

(3) 1 : 2 (4) 3 : 2

13. Velocity-time graph of an object is given below. The object has



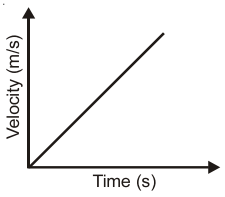
(1) Uniform velocity

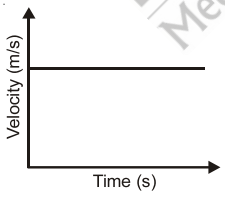
(2) Uniform speed

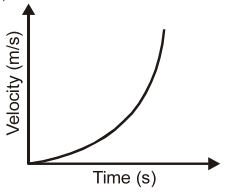
(3) Uniform retardation

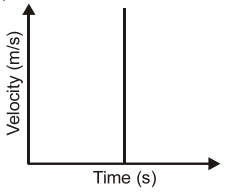
(4) Variable acceleration

14. Which one of the following velocity-time graphs is not possible?

(1) 

(2) 

(3) 

(4) 

15. The area under a velocity-time graph gives the

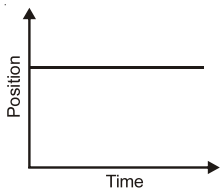
(1) Time taken by the moving object

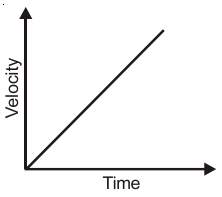
(2) Displacement of the moving object

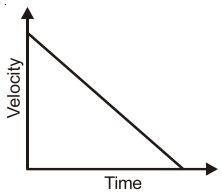
(3) Retardation of the moving object

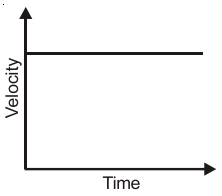
(4) Acceleration of the moving object

16. A car is moving along a straight road with uniform velocity. It is shown in the graph

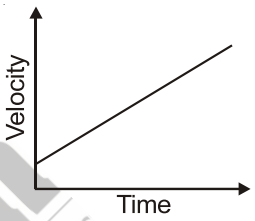
(1) 

(2) 

(3) 

(4) 

17. According to the given velocity-time graph, the object



(1) Is moving with uniform velocity

(2) Has some initial velocity

(3) Is moving uniformly with some initial velocity

(4) Is at rest

18. The slope of a velocity-time graph gives

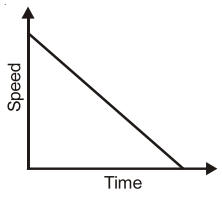
(1) Displacement

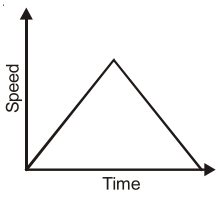
(2) Acceleration

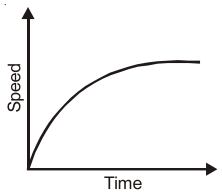
(3) Velocity

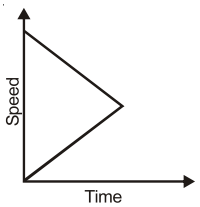
(4) Distance

19. The speed-time graph of a ball falling from certain height under gravity and rebounding from a solid surface is represented by

(1) 

(2) 

(3) 

(4) 

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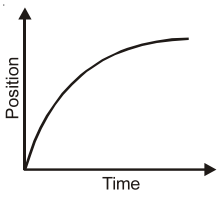
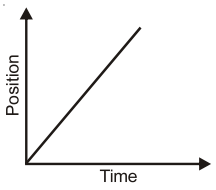
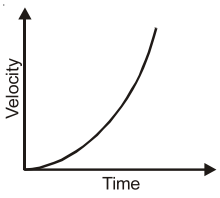
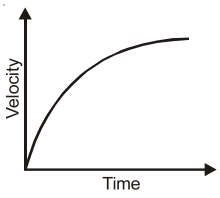
20. Which of the following graph is not showing accelerated motion of a car moving on a straight road?

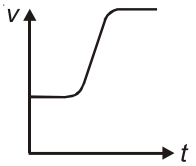
(1) 

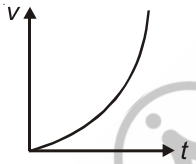
(2) 

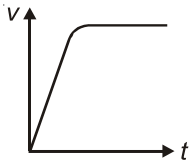
(3) 

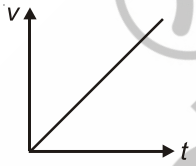
(4) 

21. Which of the following graphs represents the motion of a body moving along a straight line under constant acceleration?

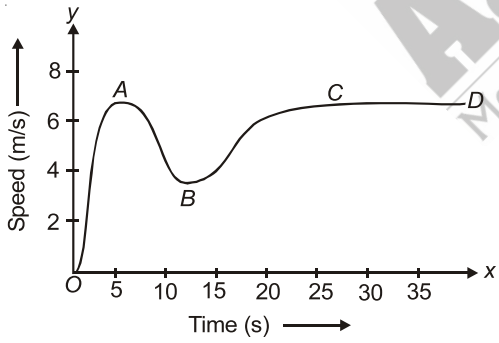
(1) 

(2) 

(3) 

(4) 

22. The speed-time graph for a car is shown.



Which part of the graph represent uniform motion?

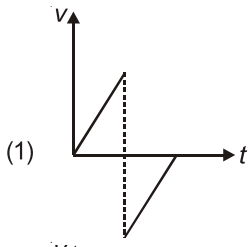
(1) *OA*

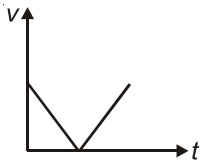
(2) *BC*

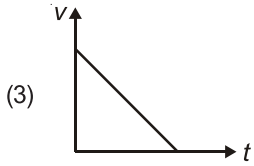
(3) *CD*

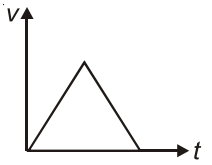
(4) *BCD*

23. A freely falling body strikes the surface and rebounds. The velocity of the body w.r.t. time during its fall and rebound is best represented by

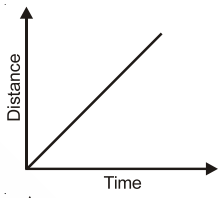
(1) 

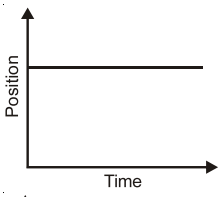
(2) 

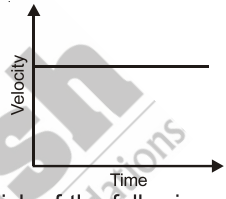
(3) 

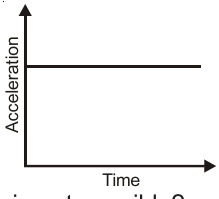
(4) 

24. Which one of the following graphs is showing that an object is stationary?

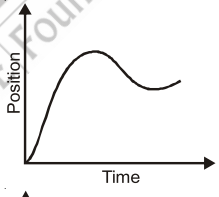
(1) 

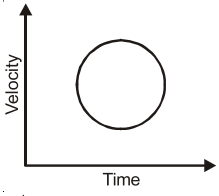
(2) 

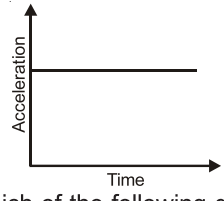
(3) 

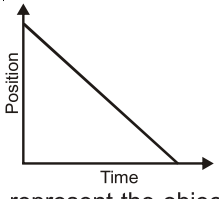
(4) 

25. Which of the following graphs is not possible?

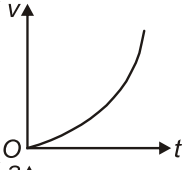
(1) 

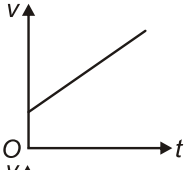
(2) 

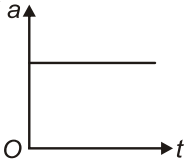
(3) 

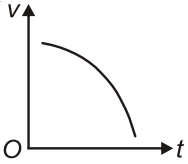
(4) 

26. Which of the following graphs represent the object moving with uniform acceleration?

A. 

B. 

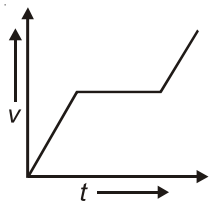
C. 

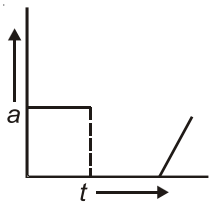
D. 

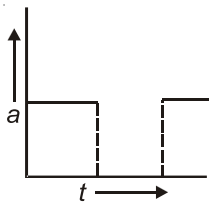
(1) Only A (2) Both B & C

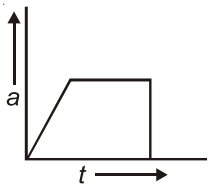
(3) Only C (4) Only B

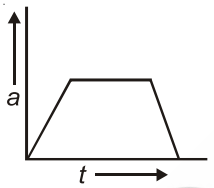
27. Which of the following would probably show the acceleration time graph for a body whose velocity-time graph is shown in figure?



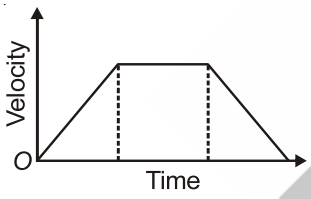
(1) 

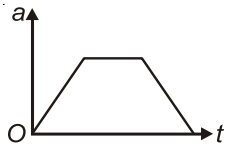
(2) 

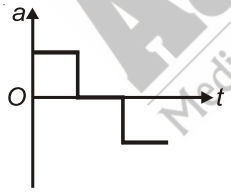
(3) 

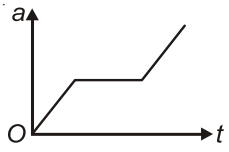
(4) 

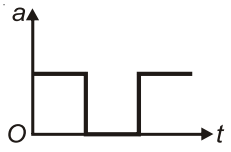
28. The velocity-time graph for a vehicle is shown below. Which among the following is the corresponding acceleration-time graph?



(1) 

(2) 

(3) 

(4) 

29. If the distance travelled by a car is directly proportional to the duration of time. The car will travel with
(1) Uniform acceleration
(2) Uniform speed
(3) Non-uniform acceleration
(4) Uniform velocity

30. The velocity of a particle increases from u to v in time t during which it covers a distance s. If the particle has a uniform acceleration, then which one of the following equations does not apply to the motion?

(1) $2s = (v + u)t$ (2) $a = \frac{v-u}{t}$

(3) $v^2 = u^2 - \frac{2a}{s}$ (4) $s = \left(u + \frac{1}{2}at\right)t$

31. A body is projected vertically upward from ground. Taking vertical upward direction as positive and point of projection as origin. The sign of displacement of the body from the origin when it is at height h during upward and downward journey will be
(1) Positive, positive
(2) Positive, negative
(3) Negative, negative
(4) Negative, positive

32. An object experiences a constant acceleration for 20 s after starting from rest. If it travels a distance x_1 in the first 10 s and distance x_2 in the remaining 10 s, then which of the following is true?
(1) $x_1 = 2x_2$ (2) $x_1 = x_2$
(3) $x_1 = 3x_2$ (4) $x_2 = 3x_1$

33. A ball is thrown up with a certain velocity. It attains a height 40 m and comes back to the thrower. The displacement of the ball is
(1) 80 m (2) 40 m
(3) 20 m (4) Zero

34. The velocity of a body moving in a straight line at the end of 5 s is 30 m/s, at the end of 12 s is 58 m/s and at the end of 22 s, it is 98 m/s. The body is moving with
(1) Uniform velocity
(2) Uniform acceleration
(3) Zero velocity
(4) Uniform retardation

35. Which of the following is true about the uniform circular motion of an object?
(1) Velocity remains constant
(2) Magnitude of velocity keeps on changing
(3) Direction of the velocity changes
(4) All of these

❑ ❑ ❑

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Chapter-1

Motion

Level-II

(For CBSE & Olympiads)

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CHAPTER 1

Motion

THIS CHAPTER INCLUDES

- Scalar and Vector Quantities
- Slope of a Line
- Acceleration-time Graph
- Distance Covered in n^{th} Second
- Uniform Circular Motion
  - Angular Displacement (θ)
  - Angular Velocity (ω)
- Relative Velocity
- Assignment

SCALAR AND VECTOR QUANTITIES

When you want to know the temperature outside so that you will know how to dress, the only information you need is a number and a unit "°C" or "°F." Temperature is therefore, an example of a scalar quantity. A physical quantity that is completely specified by a number and appropriate units is called a scalar quantity. Hence,

A scalar quantity is specified by a single value with an appropriate unit and has no direction.

Examples : Mass, distance, speed, energy, temperature etc.

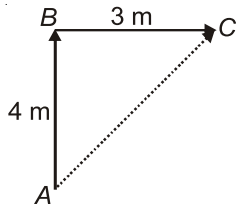
Other examples of scalar quantities are volume, work, pressure and time intervals.

The rules of ordinary arithmetic are used to manipulate scalar quantities.

If you are getting ready to pilot a small plane and need to know the wind velocity, you must know both the speed of the wind and its direction. Therefore, velocity is a vector quantity, which is defined as a physical quantity that is completely specified by a number and appropriate units plus a direction. Hence,

A vector quantity must have magnitude as well as direction and obeys the laws of vector addition.

Examples : Displacement, velocity, momentum, force, torque etc.



A particle moves from *A* to *B* and then from *B* to *C*, its displacement from its initial position is shown by the broken line from *A* to *C*.

Suppose a particle moves from point *A* to point *B* along a straight line and then it turns towards right and moves from point *B* to point *C* along a straight line. We represent the displacement of the particle by drawing an arrow from *A* to *C* with an arrow directing from initial to final position as shown by *AC* in the above figure. The length of the arrow represents the magnitude of the displacement of the particle.

By Pythagoras Theorem, the displacement will be $\sqrt{3^2+4^2} = 5$ m.

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Now, if the displacement would have been a scalar quantity then its magnitude should be the algebraic addition *i.e.*, 3 *m* + 4 *m* = 7 *m*. But this is not so, as discussed before the displacement is 5 m. This kind of addition is called vector addition and the quantities obeying this addition are always vector quantities.

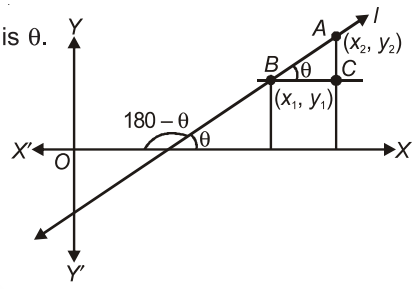
Note : *The magnitude of a vector has physical units and it is always a positive number.*

SLOPE OF A LINE

A line in a coordinate plane forms two angles with the *x*-axis, which are supplementary. The angle θ (let) made by the line *l* with *x*-axis and measured anticlockwise is called the inclination of the line. If θ is the inclination of a line *l*, then tanθ is called slope or gradient of the line *l*.

Let $A(x_2, y_2)$ and $B(x_1, y_1)$ are two points on line *l* whose inclination is θ.

$\therefore \quad \angle ABC = \theta \qquad [\because BC \parallel x\text{-axis}]$



Slope of line *l* = *m* = tanθ

$$\tan\theta = \frac{AC}{BC}$$

$$\therefore \quad m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta y}{\Delta x} = \frac{\text{Difference of ordinate}}{\text{Difference of abscissa}}$$

ACCELERATION-TIME GRAPH

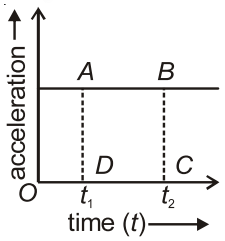
The variation in acceleration with time for a body moving in a straight line can be represented by accleration-time graph. In this graph, time is plotted on *x*-axis and acceleration is plotted on *y*-axis. From the acceleration time graph we can get the following information.

(1) We can determine the acceleration of the moving body at any particular point of time and the nature of motion.

(2) By calculating the area under the graph we can find the change in velocity in a given time interval.

(1) When the Object is Moving with Uniform Acceleration

The straight line parallel to time axis shows uniform acceleration



Calculation of Change in Velocity from Acceleration-Time Graph

To find the change in velocity for a given time internal t_1 to t_2, draw perpendicular from t_1 to t_2 such that they intersect the straight line graph *A* and *B* respectively. We get a closed figure *ABCD*

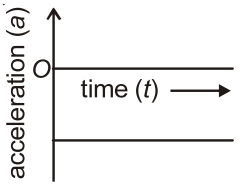
Change in velocity = acceleration × time

$$= a(t_2 - t_1) = AD \times CD = \text{Area of rectangle } ABCD$$

Thus, the area enclosed by the acceleration-time graph and the time axis gives the change in velocity of the body in a given time interval.

(2) When the Body is Moving with Uniform Retardation

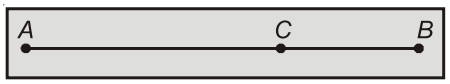
The acceleration-time graph of a body moving with uniform retardation is a straight line parallel to time-axis as shown in figure



This graph says that the acceleration is negative, the final velocity is less than the initial velocity.

DISTANCE COVERED IN n^{th} SECOND

To deduce the equation for the displacement of a body in the n^{th} second :



Let AB be the distance travelled by a body in n seconds, and AC be the distance travelled by it in $(n-1)$ seconds.

Thus the distance travelled by the body in the n^{th} second is $CB = S_n$.

$$S_n = AB - AC \quad \text{...(i)}$$

From $s = ut + \frac{1}{2}at^2$

$$AB = un + \frac{1}{2}an^2 \quad \text{...(ii)}$$

$$AC = u(n-1) + \frac{1}{2}a(n-1)^2 \quad \text{...(iii)}$$

Substituting (ii) and (iii) in (i), we get

$$S_n = un + \frac{1}{2}an^2 - \left[u(n-1) + \frac{1}{2}a(n-1)^2\right]$$

$$S_n = un + \frac{1}{2}an^2 - \left[un - u + \frac{1}{2}an^2 - an + \frac{1}{2}a\right]$$

$$S_n = un + \frac{1}{2}an^2 - un + u - \frac{1}{2}an^2 + an - \frac{1}{2}a$$

$$S_n = u + an - \frac{1}{2}a$$

$$S_n = u + a\left(n - \frac{1}{2}\right)$$

or $$S_n = u + \frac{1}{2}a[2n-1]$$

In deriving the equations we have assumed that all the vector quantities are in the same direction. However all vectors need not be in the same direction. Giving due consideration to this, '+' and '–' signs should be assigned to the quantities.

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Example 1 :

A bike moving along a straight road covers 35 m in the 4th second and 40 m in the 5th second. What is its initial velocity and acceleration (if the acceleration is assumed to be uniform)?

Solution :

Let S_4 and S_5 be the distances travelled in the 4th second and the 5th second respectively.

$S_4 = 35$ m, $S_5 = 40$ m

From the equations of motion, the distance travelled by a body in the n^{th} second is given by

$$S_n = u + a\left(n - \frac{1}{2}\right)$$

$$\therefore \quad 35 = u + a\left(4 - \frac{1}{2}\right);$$

i.e., $35 = u + \frac{7}{2}a;$

$70 = 2u + 7a$ ...(i)

Also, $40 = u + a\left(5 - \frac{1}{2}\right)$

$40 = u + \frac{9}{2}a$

$80 = 2u + 9a$ ...(ii)

Solving equations (i) and (ii), we get

$$a = \frac{10}{2} = 5\ \text{ms}^{-2}; \quad u = \frac{35}{2} = 17.5\ \text{ms}^{-1}$$

Try Yourself

1. Which of the following is not a vector?

   (1) Force (2) Momentum

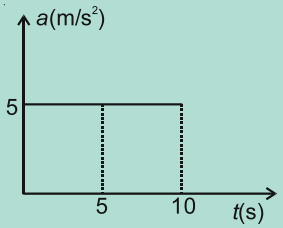
   (3) Energy (4) Velocity

2. The slope of line that passes through the points (5, 6) and (4, 3) is

   (1) 3 (2) 2

   (3) 4 (4) 6

3. The acceleration-time graph of a body is shown below. If initial velocity of body is 20 m/s, then velocity of body after 10 s is



   (1) 20 ms^{-1} (2) 40 ms^{-1}

   (3) 50 ms^{-1} (4) 70 ms^{-1}

4. A car having initial velocity 15 ms^{-1} moves with a constant acceleration of 2 ms^{-2} on a straight road. The displacement of the car in 5th second of its motion is

(1) 30 m (2) 24 m

(3) 25 m (4) 35 m

[Ans. 1(3), 2(1), 3(4), 4(2)]

UNIFORM CIRCULAR MOTION

Angular Displacement (θ)

The angular displacement of a particle moving along a circular path is defined as the angle swept out by its radius in the given time interval. It is a vector quantity, provided θ is small.

Angular Velocity (ω)

It is defined as the change in angular displacement per unit time. It is represented by omega 'ω'.

Thus,

$$\text{Angular velocity } (\omega) = \frac{\text{Change in angular position (angular displacement)}}{\text{Time taken}}$$

$$\boxed{\omega = \frac{\Delta\theta}{\Delta t}}$$

Its unit is radian/second or (rad/s). Radian is S.I. unit of plane angle θ.

Angular velocity is a vector quantity whose direction is associated as follows :

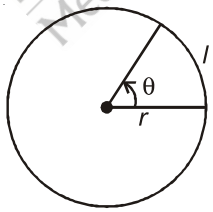
(i) For clockwise rotation, ω is directed into the plane.

(ii) For anticlockwise rotation, ω is directed out of the plane.

The magnitude of angular velocity is called angular speed.

Relation between Linear Speed and Angular Speed

One radian is the angle subtended at the centre of a circle of unit radius by an arc of unit length.



If $l = r$ = unit length

θ = 1 rad (1^C)

As we have $\theta = \frac{l}{r}$ ...(for small angles)

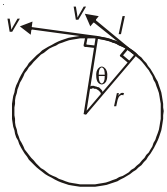
$\therefore\ l = r\theta$

Divide both sides by t

We get

$$\frac{l}{t} = r\frac{\theta}{t}$$

$\therefore\ v = r\omega$



Linear speed (v) = Angular speed × Radius of circular path

$$\boxed{v = \omega r}$$

$\omega \rightarrow$ Angular speed

$r \rightarrow$ Radius of the circular path

Example 2 :

The wheel of a cycle has a diameter 1 m. If the wheel has an angular speed of 5 rad/s, then calculate the speed of cycle in m/s.

Solution :

We have, $v = r\omega$

where,

$v \rightarrow$ Linear speed

$\omega \rightarrow$ Angular speed

$r \rightarrow$ Radius of the wheel

Given,

$\omega = 5$ rad/s, $r = 0.5$ m

$v = r\omega = 0.5 \times 5 = 2.5$ m/s

$v = 2.5$ m/s

Example 3 :

A car is moving with speed 3.5 m/s. If the radius of its tyre is 0.35 m, then calculate the angular velocity of the wheel of the car.

Solution :

We have,

$$v = r\omega$$

$$\omega = \frac{v}{r}$$

Given,

$v = 3.5$ m/s, $r = 0.35$ m

$$\omega = \frac{3.5}{0.35} = 10 \text{ rad/s}$$

$\omega = 10$ rad/s

RELATIVE VELOCITY

You must have observed how a car that is moving slowly forward appears to be moving backward when your car pass it. In general, when two observers measure the velocity of a moving body, they get different results if one observer is moving relative to the other. The velocity seen by a particular observer is called the velocity relative to that observer, or simply relative velocity. The following figure shows a situation in which understanding relative velocity is extremely important.

- When two objects A and B are moving with different velocities, then the velocity of one object 'A' with respect to another object B is called relative velocity of object A with respect to B and is given by

$$v_{AB} = v_A - v_B$$

Similarly,

Relative velocity of B w.r.t. A is given by

$$v_{BA} = v_B - v_A$$

- When A and B are moving in same direction

$$v_{AB} = v_A - (+v_B) = v_A - v_B$$

- When A and B are moving in opposite direction

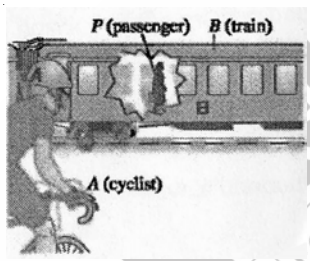
$$v_{AB} = v_A - (-v_B) = v_A + v_B$$

$$v_{BA} = -v_B - v_A = -(v_B + v_A) = -v_{AB}$$

Relative Velocity in One Dimension (Straight Line Motion)

A passenger walks with a velocity of 1.0 m/s along the aisle of a train that is moving with a velocity of 3.0 m/s (Fig.). What is the passenger's velocity? It's a simple question, but it has no single answer. As seen by a second passenger sitting in the train, she is moving at 1.0 m/s. A person on a bicycle standing beside the train sees the walking passenger moving at 1.0 m/s + 3.0 m/s = 4.0 m/s. An observer in another train going in the opposite direction would give still another answer. We have to specify which observer we mean, and we speak of the velocity relative to a particular observer.

The walking passenger's velocity relative to the train is 1.0 m/s, her velocity relative to the cyclist is 4.0 m/s, and so on.



Try Yourself

5. If a particle is moving on a circular track of radius r with angular speed ω. The linear speed of the particle will be

   (1) $\frac{\omega}{r}$ (2) $r\omega$

   (3) $\frac{r}{\omega}$ (4) $r^2\omega^2$

6. The angular velocity of a cycle wheel is 10 rad/s. If the diameter of the wheel is 80 cm, then the speed of the cycle in m/s is

   (1) 8 m/s (2) 10 m/s

   (3) 4 m/s (4) 2 m/s

7. A person enters into a circular park of radius r and moves on the circular path for t minutes and reaches at the starting point. The angular displacement of the person is

   (1) Zero

   (2) π

   (3) 2π

   (4) $2r$

8. A particle is revolving on a circular path with a constant speed. If its speed and radius of the path are doubled then its angular speed will
   (1) Get doubled (2) Get halved
   (3) Remain same (4) Get quadrupled
9. A cyclist is running at a speed of 5 m/s. If the radius of each wheel of the bicycle is 50 cm. Calculate the angular speed of the wheel.
   (1) 0.1 rad/s (2) 10 rad/s
   (3) 100 rad/s (4) 0.01 rad/s
10. A train 200 m long travelling at 80 m/s overtakes another train 400 m long travelling at 30 m/s. The time taken by the first train to pass the second train is
   (1) 20 s (2) 4 s
   (3) 10 s (4) 12 s
11. Two bikes get closer by 10 m every second while travelling in the opposite directions. They get closer by 1 m in every second while travelling in the same directions. The speeds of the two bikes will be
   (1) 5 m/s, 5.5 m/s (2) 5.5 m/s, 4.5 m/s
   (3) 4.5 m/s, 4 m/s (4) 5 m/s, 5 m/s

[**Ans.** 5(2), 6(3), 7(3), 8(3), 9(2), 10(4), 11(2)]

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Assignment

SECTION-A

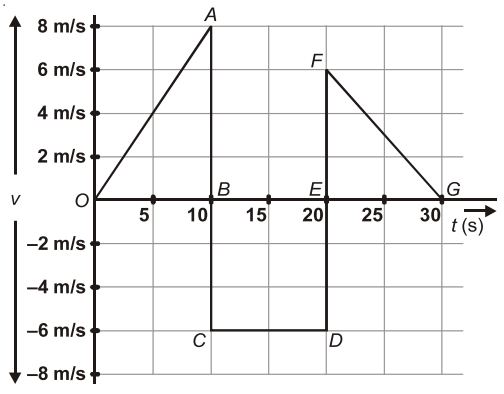
Subjective Type Questions :

1. Is displacement a scalar quantity?
2. How is linear speed of an object related to its angular speed (ω)?
3. The linear speed of the seconds hand of a wall clock is 1.05 cm/s. What will be the length of the seconds hand?
4. A scooter can produce a maximum acceleration of 5 m/s^2. Its brakes can produce a maximum retardation of 10 m/s^2. Find the minimum time in which it starts from rest, covers a distance of 1.5 km and stops again.
5. A particle moves with constant acceleration. If v_1, v_2 and v_3 are the three average velocities in three successive intervals t_1, t_2 and t_3 of time, then prove that $\frac{v_1 - v_2}{v_2 - v_3} = \frac{t_1 + t_2}{t_2 + t_3}$.
6. A car accelerates from rest at a constant rate α for some time after which it decelerates at a constant rate β to come to rest. If the total time is t prove that maximum velocity reached is $v_m = \frac{\alpha\beta t}{\alpha + \beta}$ and total displacement is $s = \frac{\alpha\beta t^2}{2(\alpha + \beta)}$.
7. A train of 150 m length is going towards North at a speed of 36 km/h. A bird is flying at 18 km/h parallel to track towards South. Find the time taken by the bird to cross the train.
8. A train is moving with uniform acceleration. The two ends of the train pass through a point on the track with velocity v_1 and v_2. With what velocity the middle point of the train would pass through the same point?
9. Two cars leave with a time gap of 1 minute from the same point. They move with an acceleration of 0.2 m/s^2. How long after the departure of the second car, does the distance between them become equal to three times its value, when the second car just starts?
10. A rifle bullet loses $\frac{1}{20}$ th of its velocity in passing through a plank. Find the least number of such planks required to just stop the bullet

SECTION-B

Objective Type Questions :

1. We can conveniently obtain the information about the nature of motion of an object using graphs. The velocity-time graph of an object moving along a straight line is shown in the figure.



The distance covered by the object from t = 0 to t = 10 s is

(1) 40 m (2) 50 m

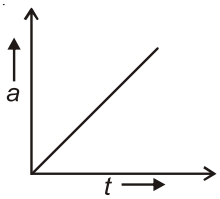
(3) 60 m (4) 30 m

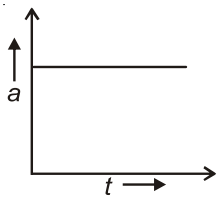
2. What does the area of an 'acceleration-displacement' graph of a uniformly accelerating body represent?

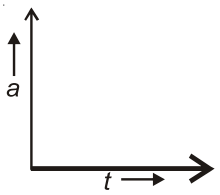
(1) Velocity (2) $\frac{v^2 - u^2}{2}$

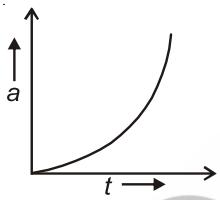
(3) Distance (4) Acceleration

3. Which of the following is the acceleration-time graph of an object having uniform motion?

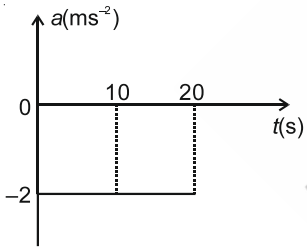
(1) 

(2) 

(3) 

(4) 

4. The acceleration-time (a-t) graph of a particle moving with initial speed of 45 m/s is shown below. The velocity of body at t = 20 s is



(1) 10 ms^{-1} (2) 4 ms^{-1}

(3) 5 ms^{-1} (4) 8 ms^{-1}

5. A body is moving in a straight line with initial velocity u and uniform acceleration a. Sum of the distances travelled in n^{th} and $(n + 1)^{th}$ seconds is 50 m. If v is its velocity after n seconds and u = 5 m/s, then $\frac{v}{u}$ is

(1) 5 (2) 10

(3) 15 (4) 20

6. Two cars A and B moving in opposite direction along a straight road with constant velocities of 20 m/s and 40 m/s respectively. Velocity of B with respect to A is

(1) 20 m/s (2) 30 m/s

(3) 60 m/s (4) 80 m/s

7. Two trains having length 200 m and 332 m are running in the opposite directions with velocities 54 km/h and 72 km/h. In what time they will completely cross each other?

(1) 15.2 s (2) 16.2 s

(3) 15.8 s (4) 16.8 s

8. If an object moves a circular distance s of radius r, then its angular displacement is

(1) $\frac{s}{r}$ (2) $\frac{r}{s}$

(3) rs (4) r^2s

9. If the linear speed of minute hand of a wall clock is 3.14×10^{-4} m/s then, the length of the minute hand will be

(1) 18 cm (2) 1800 cm

(3) 3.14 cm (4) 314 cm

10. The wheel of a car is running at a speed of 50 m/s if the angular speed of the wheel is 500 rad/s then, the radius of the wheel is

(1) 50 m (2) 1 m

(3) 0.1 m (4) 0.2 m

SECTION-C

Assertion & Reason Type Questions :

In the following questions, a statement of assertion (A) is followed by a statement of reason (R).

(1) If both Assertion & Reason are true and the reason is the correct explanation of the assertion, then mark **(1)**.

(2) If both Assertion & Reason are true but the reason is not the correct explanation of the assertion, then mark **(2)**.

(3) If Assertion is true statement but Reason is false, then mark **(3)**.

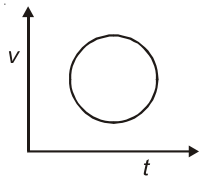
(4) If both Assertion and Reason are false statements, then mark **(4)**.

1. A : Average velocity of a moving body can be zero but its average speed cannot be zero.

R : Displacement can be zero but distance travelled cannot be zero for a moving object.

2. A : An object moving with a constant acceleration can have zero velocity.
   R : A moving object having zero acceleration has zero velocity.

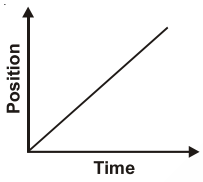
3. A : The following graph is not possible.



   R : There are two velocities at the same time, so it is not possible.

4. A : In uniform circular motion, the particle moves with constant speed but not with constant velocity.
   R : In circular motion direction of motion of the particle changes with time.

5. A : The position-time graph in the figure represents uniform motion.



   R : The particle changes its position with time.

SECTION-D

Match the Columns Type Questions :

1. Match the following :

	Column I		Column II
a.	Straight line parallel to time axis in velocity-time graph	(i)	Body at rest
b.	Straight line parallel to time axis in position-time graph	(ii)	Body in uniform motion
c.	Straight line parallel to position axis in position-time graph	(iii)	Body having uniform acceleration
d.	Straight line inclined to 45° with time axis in velocity-time graph	(iv)	Not possible

(1) a(ii), b(i), c(iv), d(iii) (2) a(i), b(ii), c(iii), d(iv)
(3) a(iii), b(ii), c(i), d(iv) (4) a(iv), b(iii), c(ii), d(i)

2. Match the following :

	Column I		Column II
a.	Uniform motion	(i)	Velocity-time graph is a curve
b.	Non-uniform motion	(ii)	Straight line parallel to time axis in velocity-time graph
c.	Straight line parallel to position axis in position-time graph	(iii)	Unequal distances covered in equal intervals of time
d.	The velocity-time graph is a circle	(iv)	Not possible
		(v)	Equal distances covered in equal intervals of time

(1) a(ii, v), b(i, iii), c(iv), d(iv)
(2) a(iv), b(iii), c(ii), d(i)
(3) a(iv), b(v), c(iii), d(ii)
(4) a(i), b(iv), c(v), d(ii)

3. Match the following :

	Column I		Column II
a.	Constant speed with varying velocity	(i)	At highest point of a body projected vertically up
b.	The velocity of a body having finite acceleration is zero	(ii)	Uniform circular motion
c.	Zero displacement and finite distance	(iii)	Body reaching on point of projection
		(iv)	A body moving on circular track with speed 2 m/s and complete one revolution

(1) a(ii, iv), b(i), c(iii)
(2) a(ii), b(i), c(iii)
(3) a(ii, iv), b(i), c(iii, iv)
(4) a(ii), b(i), c(iii, iv)

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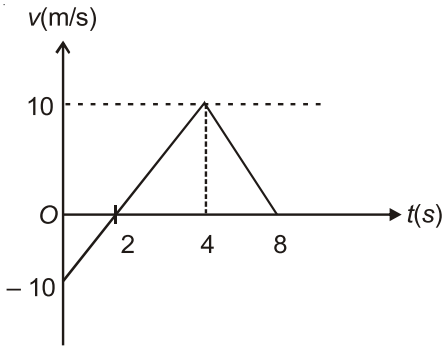
4. For the velocity-time graph shown in figure, match the following columns



	Column I		Column II
a.	Constant acceleration	(i)	t = 0 to t = 2 s
b.	Zero displacement	(ii)	t = 2 s to t = 4 s
c.	Increasing speed	(iii)	t = 0 to t = 4 s
d	Negative displacement	(iv)	t = 4 s to t = 8 s

(1) a(i, ii, iii, iv), b(iii), c(ii), d(i)

(2) a(i, iv), b(iii), c(ii), d(i)

(3) a(i, ii, iv), b(iii), c(ii), d(i)

(4) a(i, ii), b(iii), c(ii), d(i)

5. Match the following :

	Column I		Column II
a.	Motion of freely falling body	(i)	Retardation
b.	Reading of speedometer	(ii)	Average speed
c.	Movement of tips of hands of a clock	(iii)	Non-uniform motion
d.	Brakes applied on a moving car	(iv)	Uniform circular motion
		(v)	Instantaneous speed

(1) a(iv), b(ii), c(iii), d(i) (2) a(iii), b(ii), c(iv), d(i)

(3) a(iii), b(v), c(iv), d(i) (4) a(iv), b(v), c(iii), d(i)

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